ACE

Aerosol, Cloud, & Ecosystem Mission

Tier-2 Decadal Survey Mission

David Starr, NASA Goddard Space Flight Center
ACE Study Lead Scientist

Ocean Lead: Charles McClain, NASA Goddard Space Flight Center
Aerosol Lead: Lorraine Remer, NASA Goddard Space Flight Center
Cloud Lead: Jay Mace, University of Utah
Suborbital Science Lead: Jens Redemann, NASA/Ames Research Center
Mission Study Leads: Lisa Callahan (NASA/GSFC) & Armin Ellis (Jet Propulsion Lab)

NASA Headquarter Leads
Hal Maring & Paula Bontempi

ACE Mission

ACE Objective: "…reduce the uncertainty in climate forcing in aerosol-cloud interactions and ocean ecosystem CO_2 uptake" –

NAS Decadal Survey (2007) pg 4-4

ACE is the **only** Tier 1 or Tier 2 Mission focused on Aerosols and Clouds, and their interactions, including effects on precipitation.

ACE addresses the largest uncertainty in understanding of physical climate, that due to aerosols and clouds (IPCC, 2007) .

ACE was the **only** mission recommended by 3 Decadal Survey panels (climate, hydrology, weather).

ACE Mission

ACE is *the* successor to a core complement of A-Train sensors and science that has been, and is today, highly productive.

ACE represents a substantial step forward, **beyond the A-Train and EarthCare**, in remote sensing capability, for Aerosols, Clouds *and* Ocean Ecosystems, **enabling critical science progress**, especially with regard to **physical processes.**

ACE is highly synergistic

Atmospheric correction for ocean ecosystem characterization

Interactions of aerosols and ocean ecosystems

Interactions of aerosols and clouds, including precipitation

ACE Mission

ACE is focused on describing physical processes, e.g.,

- ***Phytoplankton speciation => critical for CO_2 uptake assessment***
- ***Aerosol composition and properties => critical for DARF***
- ***Cloud microphysical profiles => critical for aerosol-cloud interaction***

These are each new capabilities and will be achieved with suitable accuracy to move the science forward in a major way.

ACE Mission

More than 2 years of intensive work have been done by a large multidisciplinary team of expert scientists to arrive at the Science Traceability charts that have been shown here, including many science trade studies, many many hours of scientific debate, and outreach to the broader community. A Final Draft Report has been produced. It is deep and hefty.

Much has been invested in developing technology and airborne simulators for ACE instruments, via ESTO and every other means we could find. Much has been accomplished.

Mission architectures have been explored and studied (MDL and Team X)

ACE Mission

ACE could launch in 2020, or earlier, if prioritized, directed and adequately funded. There are no technology show stoppers.

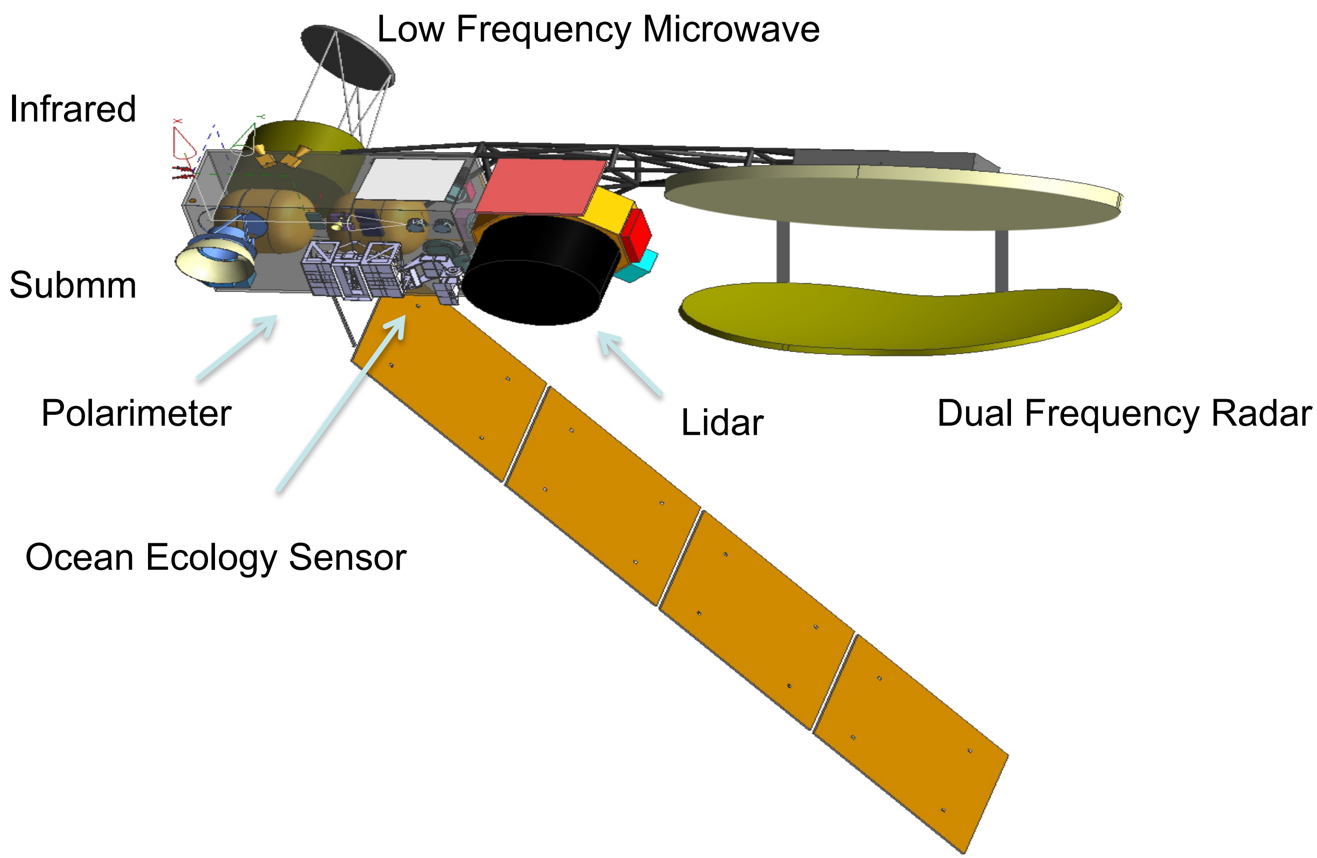
ACE costs could be significantly reduced if International Partners could be found. In particular, formation flying with a mission that contained an *infrared imager*, a conically-scanning *low-frequency microwave sensor*, such as GMI or AMSR-2, and a conically-scanning *submillimeter radiometer* would be ideal.

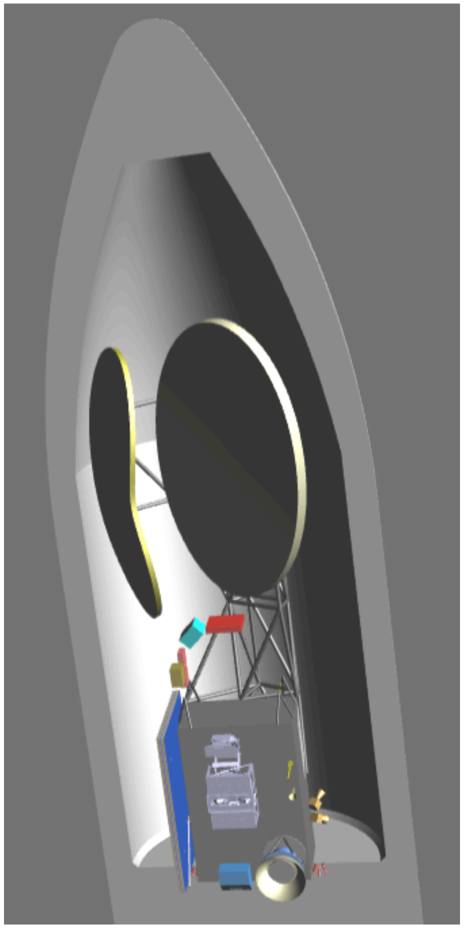
Potential challenge to International Partnerships is the proposed ACE orbit height of ~450 km. EarthCare has similar issue (405 km).

A-Train & GCOM-W at 705 km, NPP & JPSS at 830 km

To achieve international partnerships will require agency-to-agency negotiation at high levels.

ACE Payload configuration





ACE Mission – Path Forward

Algorithm Development – New & evolved sensors

Acquisition of Data to Support Algorithm & Sensor Development

- Airborne Simlulators for ACE sensors
- In-situ sensors for truth data
- Field Campaigns
- Data processing and analysis support

Technology investment toward robust space qualified and optimized sensors

Modeling

- Forward Models for new and evolved sensors
- Observing system assessments
- Data assimilation – a key pathway for science

Mission Architecture – Next Steps

ACE Mission – Path Forward

Algorithm Development – New & evolved sensors

Big step forward from what we have in space !!

- Ocean Ecosystem Sensor – many more channels, new geometry
- Polarimeter – moderately high-resolution, wide-swath, UV-SWIR data, building on and beyond Glory and other predecessor missions
- HSRL – major step forward ($3\beta+2\alpha+2\delta$) from CALIOP ($2\beta+1\delta$)
- Radar – W (CloudSat) + K_a (GPM) together, with Doppler (EarthCare)
- Submillimeter – new channels and new geometry (versus MLS)

Each has new products !!!

AND !!!! **Multi-sensor products** (recent A-Train developments) => clouds

ACE Mission – Path Forward

Acquisition of Data to Support Algorithm & Sensor Development

Airborne Simulators (integrated for high-altitude sensing)

- Ocean Ecosystem Sensor Simulator (in development*)
- Polarimeter – 3 approaches in development (RSP, MSPI*, PACS*)
- HSRL – airborne ($3\beta+2\alpha+2\delta$)* in development
- Radar – W-band: CPR being refurbished, others could be integrated
  - K_a–band: APR-2, HIWRAP (needs increased sensitivity)

  => We need a true ACE Simulator Radar*

- Submillimeter – CoSSIR (recently updated)
- Microwave – CoSMIR (recently refurbished for GPM Cal/Val)
- IR Imager – eMAS (MAS replacement being built)

* IIP or AITT pending

ACE Mission – Path Forward

Acquisition of Data to Support Algorithm & Sensor Development

In-situ sensors for truth data

- Aerosol absorption measurements
- Ocean Ecosystem Sensor Vicarious Calibration Technology
  (extended spectral range and resolution, e.g., OSPREy)
- Enhancement of various in-situ measurement capabilities
  (particles, phytoplankton, carbon, fluorecence, etc)

Field Campaigns (near term)

PODEX: Intercomparison of polarimeter approaches & HSRL
=> GLORY SDR Validation (piggyback)
=> SEAC4RS EDR Validation (piggyback)

ACE Radar Proof-of-Concept Data Sets
=> pre-SEAC4RS test flights over stcu
=> TC4, CRYSTAL-FACE, and Aqua Val Wakasa Bay analysis

Ocean Ecosystem Data Collections (well targeted)

ACE Mission – Path Forward

Acquisition of Data to Support Algorithm & Sensor Development

Data processing and analysis support – This is critical and often neglected.

Technology investment toward robust, space-qualified, optimized sensors

UV Laser Lifetime Assessment – do this immediately

Interferometric Receiver - Assess candidate approaches (gnd & airborne)

Detectors - space qualification of candidate detectors (532 and 355 nm)

Ka/W High Power Amplifier

Ka/W Antenna System, including phased-array approaches

Polarimetric imaging system detectors, readouts, calibration

Modeling

Forward Models for new and evolved sensors

Observing system assessments (orbits, mission architecture)

Data assimilation – a key pathway for science => CLOUDS !!!

ACE Mission – Path Forward

Mission Architecture – Next Steps

- Select baseline architecture and perform more detailed design on mission implementation
- Pursue international collaboration consistent with mission concept and orbit analyses
- Initiate independent cost estimate
- Continue and expand mission systems engineering activities including Risk definition

ACE Mission Summary

ACE is the Climate Prediction Mission !

In the absence of significant progress in knowledge and understanding of aerosol-cloud-precipitation linkages and interactions that ACE will provide, progress in reducing the outstanding major uncertainties in future climate prediction will be limited.

ACE is the critical next step required to understand the role of the atmospheric aerosol-cloud-precipitation processes in the global hydrologic cycle, energy budget and climate change. ACE offers major observational advances.

ACE is the next step required to describe the global ocean ecosystems at a level of detail and accuracy required determine their role in the global carbon cycle.

ACE Mission Summary

Backup Slides

ACE White Paper Draft Outline

Chapters have been submitted by the discipline working groups and are being synthesized for final editing and publication.

- Executive Summary
- Chapter 1. Aerosols
- Chapter 2. Clouds
- Chapter 3. Aerosol-Cloud Interactions
- Chapter 4. Ocean Ecosystems
- Chapter 5. Ocean-aerosol Interactions
- Chapter 6. Synergistic Science (Suborbital Program)
- Chapter 7. Science Synthesis and Linkages (Modeling & Assimilation)
- Chapter 8. Instrument Requirements
- Chapter 9. Mission Formulation
- Chapter 10. Calibration and Validation
- Chapter 11. Mission Cost and Phasing Options

ACE Instruments

- **Lidar** for aerosol/cloud heights, aerosol properties, & ocean particle load (TRL 3-4)
  Two options: multi-beam system or high spectral resolution lidar (HSRL)
  - **HSRL** driven by science requirement to distinguish aerosol types/composition
  - Multi-beam system driven by desire for greater area coverage/sampling
- **Dual-frequency cloud radar** for cloud properties and precipitation (TRL 4-6)
  - W-band (94 GHz) with Doppler to ±0.4 m s^{-1}
  - Ka-band (35 GHz) with Doppler to ± 1 m s^{-1}
  - Strongly recommended goal: Ka-band scanning over swath > 25 km
- **Polarimeter:** Multi-angle, multi-spectral, swath for imaging aerosol and clouds (4-6)
- **Ocean ecosystem spectrometer (OES):** multi-spectral uv-vis, wide-swath(5)
- **IR multi-channel imager** for cloud temperatures and heights (TRL 6)
- **High-frequency microwave swath radiometer** for cloud ice water path & D_e (TRL 6)
- **Low-frequency microwave swath radiometer:** cloud liquid water path & precipitation(8)

ACE Mission Development Activities

- Initial Mission Studies conducted by GSFC and JPL - 2007
- ACE formulation team defined – Spring 2008
  - Aerosol, Cloud, Ocean, Suborbital working groups *
- Science definition team meetings
  - 2008 - NASA GSFC, Hawaii (w/Japanese), Univ. of Utah
  - 2009 – Oxnard, Santa Fe (open), Columbia
- ***Science-to-Requirements 'White Papers'***
  - Drafts completed for each discipline and cross-discipline
- ***Science Traceability Matrices***
  - Completed for each discipline and cross-discipline
- ***GSFC Mission Design Lab and JPL Team-X studies conducted***
  - Various instrument and spacecraft combinations including a phased-ACE implementation (PACE + ACE)

Near-term Future of Multisensor Remote Sensing of Aerosols and Clouds from Space

- EOS A-Train platforms, including CloudSat and CALIPSO, are all past prime mission and their nominal design life.
  - Due to low solar cycle 23 minimum, the EOS platforms will likely be de-orbited in 2018, or later.
  - MODIS on Aqua should still be operating in **2014** (85%).
  - CALIPSO and CloudSat could last into **2014** as well
    - CloudSat dictated by spacecraft battery and high power amplifier.
    - CALIPSO dictated by laser lifetime.
- **GCOM-W1 launch in 2011** (AMSR-2) => into A-Train
- **NPP launch in Oct 2011** (VIIRS, CrIS, ATMS, OMPS)
  - NPP & JPSS not planned to formation fly with other platforms.
- **EarthCare launch in 2014** (ATLID, CPR, MSI, BBR)
  - EarthCare not planned to formation fly with other platforms.
  - EarthCare orbit is ~400 km and no wide-swath sensors.

ACE Suborbital Program

Pre-Launch	Post-Launch
1) Instrument development Develop suborbital instrument simulators and cal/val field instruments.	1) Cal/val for orbital instruments Cal/val/testing of the ACE orbital instruments through designated campaigns.
2) Algorithm development Support algorithm development for the suite of ACE sensors based on existing data sets. Carry out designated field campaigns to support algorithm development for specific sensor combinations.	2) Continued algorithm development Continue support of algorithm development based on suborbital data.
3) Cal/val for suborbital simulators Testing of design concepts for the ACE orbital instruments through designated cal/val campaigns for suborbital simulators.	3) Sustained science Operate a suite of suborbital platforms and sensors in major field experiments and sustained activities capable of integrated science contributions as defined by overall mission objectives.